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EFFECTS OF AERIAL APPLICATION OF DDT FOR TUSSOCK MOTH CONTROL ON NESTLING SURVIVAL OF MOUNTAIN BLUEBIRDS AND HOUSE WRENS

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Abstract

Observations were made on 12 mountain bluebird (*Sialia currucoides*), 1 Western bluebird (*S. mexicana*), and 9 house wren (*Trogodytes aedon*) nests in northeast Oregon following aerial application of 0.75 lb per acre of DDT to control Douglas-fir tussock moth (*Orygia pseudotsugata* McDonnough). Nests were checked at intervals to determine if nestling mortality occurred from starvation due to a lack of insect food or direct DDT intoxication. Eggs laid, eggs hatched, and nestling survival were compared with control areas of 47 mountain bluebird, 9 Western bluebird, and 5 house wren nests. The majority of nests were located in nest boxes (350 boxes in nonspray and 200 in spray areas) erected to attract nesting birds for study. Spray was applied after egg laying and incubation were complete or underway. No significant difference in nestling survival between spray and nonspray areas was detected.

Keywords: DDT monitoring, bluebirds, house wrens, bird reproduction effects.

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Introduction

THE PROBLEM

During June-July 1974, 426,159 acres of forested land were sprayed with DDT in northeastern Oregon, southeastern Washington, and adjacent Idaho to control Douglas-fir tussock moth (*Orygia pseudotsugata* McDonnough). An environmental impact statement (USDA Forest Service 1973) gave the rationale on which the request to the Environmental Protection Agency (EPA) for DDT use was based. The agency had previously banned DDT for this use.

EPA gave approval but required intensive monitoring, of which this study was a part.

We sought to determine if DDT application had adverse, short-term effects on reproductive performance of insectivorous birds. Because of time and resource limitations, we further limited the study to cavity-nesting, insectivorous birds.

CHEMICAL APPLICATION

DDT (0.75 lb) mixed with 0.94 quart of auxiliary solvent and enough No. 2 fuel oil to make 1 gallon was sprayed from helicopters at approximately 0.75 lb DDT per acre. This rate was applied to 420,944 acres including our study areas. Another 2,530 acres were sprayed at 0.50 lb per acre and 3,085 acres, at 0.25 lb per acre. The spray was shut off over grassland openings of more than 2 acres (Rod Canutt, Monitoring Coordinator, personal communication) which was important because many insectivorous bird species feed there.

Methods

NEST BOXES

Nest boxes were constructed similar to Schutz' description (1974, p. 132) and placed at minimum intervals of 200 feet to attract cavity-nesting birds, particularly mountain bluebirds (*Sialia currucoides*), Western bluebirds (*S. mexicana*), and house wrens (*Troglodytes aedon*).

SPECIES SELECTION

Mountain bluebirds, Western bluebirds, and house wrens were selected because:

1. They are insect feeders with 90 percent or more of the spring and summer diet composed of insects (Martin et al. 1951, Beal 1915, Bent 1948, 1949, and Knowlton and Harmston 1946).

2. They commonly nest within the outbreak areas (Gabrielson and Jewett 1940).

3. They are cavity nesters and can be attracted to nest in boxes (Headstrom 1970, Gabrielson and Jewett 1940, Peterson 1961).

4. Their preferred habitat is open conifer woodland or ecotones between forest edge and grassland openings as depicted in figure 1 (Gabrielson and Jewett 1940, Peterson 1961).

5. They nest 4 to 6 feet above the ground (Headstrom 1970).

Figure 1.--Typical ecotone habitat between mixed conifer and grassland openings where nest boxes were located.

The foregoing were important, respectively, because:

1. The study concerned cavity-nesting, insectivorous birds; the chance to study several species provided a "fail safe" mechanism that increased the likelihood that data would be obtained.

2. The more common the species, the greater the likelihood of obtaining adequate samples.

3. Bird boxes attract birds to areas easily reached by us and the contents could be easily inspected.

4. The forest-grassland could be easily followed on the ground and seen on aerial photographs, greatly facilitating both finding the boxes and checking them.

5. Nests could be examined without climbing (fig. 2).

Figure 2.--Nest boxes were located at a height suitable for easy examination.

REPRODUCTIVE SUCCESS

Boxes were checked at intervals ranging from 2 to 21 days with variations due to spray schedules and weather. Boxes were opened (fig. 3) on each visit and the contents described as follows:

1. Number of eggs (fig. 4).

2. Condition of eggs--broken, whole, or pipped.

3. Number of young (fig. 5).

4. Condition of young--alive or dead, physical condition.

5. Approximate age of young--0, 25, 50, 75, and 100 percent of fledging size.

6. Number of young fledged.

Reproductive success for each species was measured and compared as follows.

1. The mean of the eggs laid per clutch was compared between spray and nonspray areas using the t-test.

2. Egg fertility of spray and nonspray areas was compared by tabulating hatched and unhatched eggs and testing comparability by means of chi-square.

Numbers of eggs laid and egg fertility were not influenced by DDT due to the time

Figure 3.--Bird boxes were constructed so that they could be opened for easy examination of the contents.

Figure 4.--The number of eggs and their condition were determined by careful examination.

Figure 5.--Nestlings were counted and their age and physical condition determined.

of spray application. These measures of reproductive performance were compared for spray and nonspray areas only to give some measure of the comparability of the areas. Reasons for any differences were not known, but differences were not associated with current DDT spray.

3. Nestling mortality was determined by counting dead young and assuming others had flown the nest; results for spray and nonspray areas were compared by the chi-square.

4. Fledging was assumed when the nest previously containing young was no longer occupied, they were healthy at last examination, they would have been developed enough to depart, and no dead young were found in the box or nearby. Such data were circumstantially derived. So, nestling survival in spray areas was also examined by determining the known days young survived postspray. We emphasize that fledging data are circumstantially derived, unless the young are actually observed leaving the nest. Just how much faith should be placed in the assumption of fledging is debatable. The probability of the interpretation of fledging being correct was probably related to the time elapsed between the last nestling examination, the assumed fledging date, and the time lapse from that date to the next examination.

So, probable hatching and fledging dates were derived from the "best estimator" available from the field data. For example, if the eggs were in the process of hatching when the nest was examined, this was taken as the best estimator of the hatching date. Then 16 days (Bent 1948 and 1949) were counted from that date to derive the probable fledging date.

The ages or sizes of the nestlings were estimated as 0, 25, 50, 75, or 100 percent of fledging age or size. This crude index was also used, in the absence of other data, as best estimator of hatching and fledging dates. Probable hatching and fledging dates were derived by counting forward and backward from the last date the nestlings were observed, allowing 4 days per 25-percent size or age class. For example, if the young were at 75 percent of fledging stage on last examination, the hatching date was derived by counting back 12 days and, conversely, estimating the fledging date by counting forward 4 days.

5. The chronology of activities in each nest was displayed and scrutinized for patterns and data deviation.

DDT REACHING GROUND LEVEL

DDT reaching the ground was measured from three 4- by 5-inch oil-sensitive cards (White 1959) placed near each box 12 to 24 hours before and removed 12 to 24 hours after spray application. No cards were placed on boxes in the nonspray areas. Boxes were located in the forest-grassland ecotone; and we sampled at the box, 60 feet from the box, in the open, and a like distance inside the wooded area for an estimate of the DDT delivered at ground level to the area. Cards were placed at ground level at the prescribed point. Many cards were under shrubs or surrounded by grasses.

Cards were analyzed as described by Maksymiuk (1963a) and Davis and Elliott (1953).

The mean value of the cards was considered the DDT level at that box. We assumed that the DDT estimate was representative of that territory. These levels were considered critical, as wrens and bluebirds are said to feed primarily on ground-dwelling insects (Martin et al. 1951).

Data on an additional 490 card distributed over our study areas to check the overall spray results were made available by the U.S. Forest Service, Region 6.

INSECT RESPONSE TO DDT APPLICATION

Insect response to DDT was estimated from malaise-type net traps described by Butler (1965) and shown in figure 6. Two were placed near each cluster except for the two McAllister Ridge clusters which had one each. The measure of flying insect population was the biomass trapped per trap per day (fig. 7). This was considered as a crude index of the general insect population. Such traps operated in New York (Matthews and Matthews 1970) captured the following orders: Diptera (44.7 percent), Plecoptera (20.8), Hymenoptera (14.7), Lepidoptera (7.2), Hemiptera (7.1), and Coleoptera (2.4). We emphasize that such traps trap flying insects and not the ground-dwelling insects on which bluebirds and house wrens feed. Thus we considered these data only a crude index of the effect on insects as a whole.

Figure 6.--Malaise insect traps were used to obtain relative measures of the flying insect population. A side of the net has been removed to make it function like a backstop. Insects fly into the net and then continue to fly upward until they enter the plastic bag where they are killed by an insecticide.

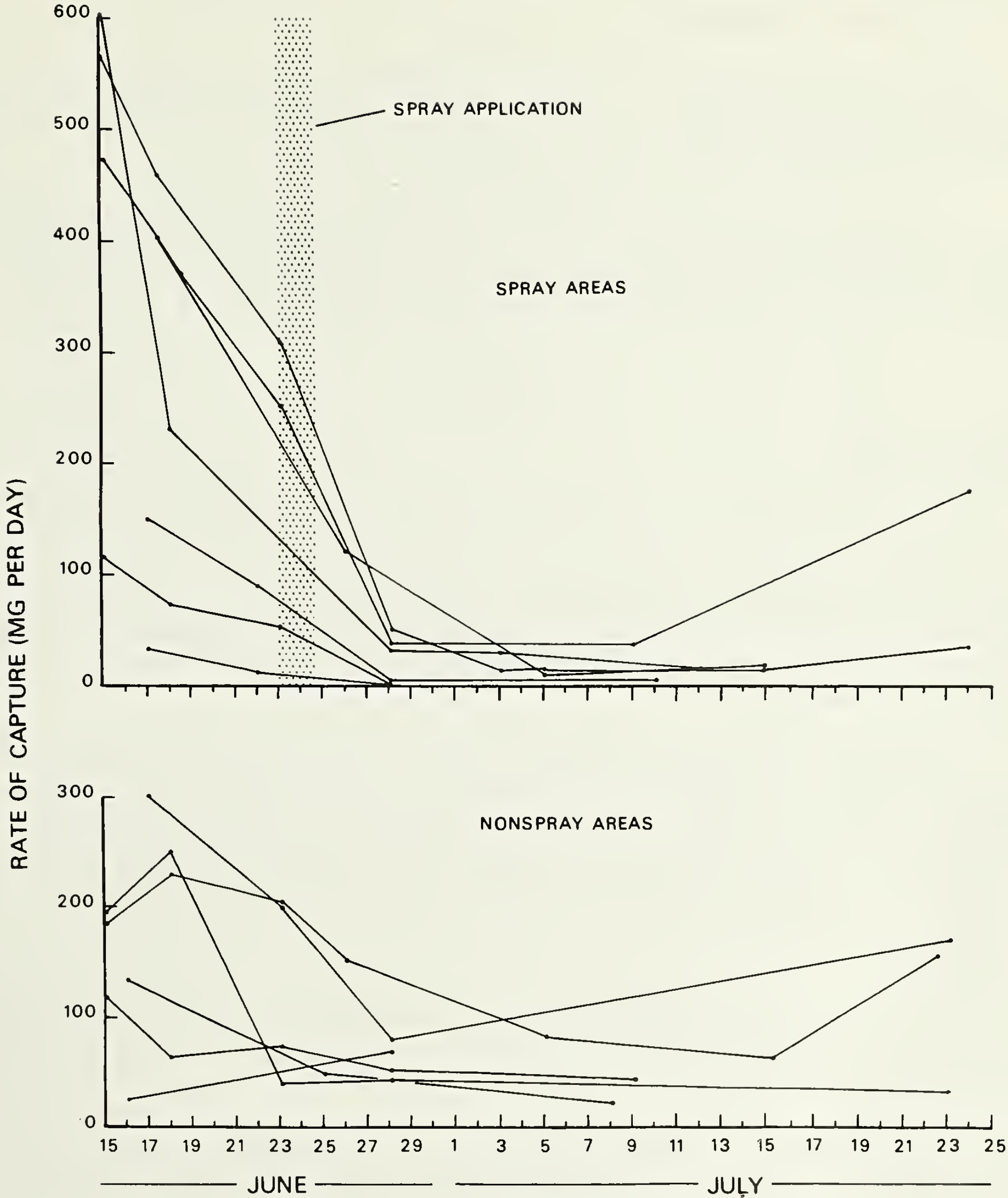

Figure 7.--Rate of insects trapped over time.

INSTALLATION OF BIRD BOXES

Between April 26 and May 22, 1974, 550 nest boxes were installed in 11 clusters of 50 boxes each (table 1) while spray areas were still tentative. Six clusters were in designated spray areas and five in other areas.

As a result of late changes in the spray program, 4 clusters (200 boxes) were sprayed and 7 clusters (350 boxes) were not. Sprayed clusters were separated from controls by at least 0.5 mile. Operational restrictions on wind velocities suitable for spraying made it probable that spray drift did not occur between areas.

Results

DATA TREATMENT

The total data on which the remainder of the paper is based are given in appendixes 1-16. Mountain bluebird nest data for the spray areas are treated in appendix 1 and for control areas in appendix 2. Similar data for house wrens is given in appendixes 3 and 4, and for Western bluebirds in appendixes 5 and 6. Summaries are shown in table 2. The data for each nest for each species was arranged in a display depicting event chronology (appendixes 7 and 8 for mountain bluebirds, 9 and 10 for house wrens, and 11 and 12 for Western bluebirds).

In most cases, DDT was applied after clutches were complete (appendixes 7, 9, and 11 and fig. 8) and would not have influenced clutch size or egg fertility. However, the data were tested to examine comparability between spray and nonspray areas to detect if habitat attribute(s) might have affected these reproductive measures. Clusters were ignored as a variation source due to small numbers available for testing.

CLUTCH SIZE

Clutch size for mountain bluebirds averaged 5.3 in the spray area and 5.2 in the nonspray area. Results of t-test ($t = 0.5840$, degrees of freedom = 57, $p = 0.05$) indicated no significant difference in means.

For house wrens, the clutch averages were 6.7 in the spray area and 5.4 in the nonspray area, and they were significantly different ($t = 2.4010$, degrees of freedom = 12, $p = 0.05$). The reason for this difference was not known, but it was not connected with DDT.

EGG FERTILITY

Fertility of areas was compared by the number of eggs hatched and failed to hatch. For mountain bluebirds (appendixes 1 and 2) the chi-square test for independence with correction for continuity revealed ($\chi^2 = 0.65$, degrees of freedom = 1, $p = 0.05$) no significant difference.

For house wrens (appendixes 3 and 4), the same test revealed no significant difference in egg fertility ($\chi^2 = 0.27$, degrees of freedom = 1, $p = 0.05$).

Table 1.--*Location and description of nest box clusters--50 boxes per cluster (total 550 boxes), northeastern Oregon, 1974*

Cluster	Cluster name	Date installed	Boxes occupied		Treatment	County	Section
			-*Number*-	-*Percent*-			
1	Fox Prairie	April 26	4	8	Nonspray	Umatilla	26,35,36
2	Y Ridge	April 29	10	20	Nonspray	Umatilla	6,7
3	Spring Creek	April 30	6	12	Nonspray	Union	21,27,28
4	Interstate	May 1	3	6	Nonspray	Union	26,27
5	Starkey Ridge	May 3	8	16	Nonspray	Union	11,12,14,21
6	Sled Springs	May 6	6	12	Nonspray	Wallowa	25,26
7	Starvation Ridge	May 7	13	26	Nonspray	Wallowa	7,13,18
8	McAllister	May 8	4	8	Spray	Wallowa	12,13,18
9	McAllister Ridge	May 10	4	8	Spray	Wallowa	19,30,31
10	Horseshoe Ridge	May 13	10	20	Spray	Umatilla	18,20,29
11	Powatka Ridge	May 22	2	4	Spray	Wallowa	21,28
All boxes			1/ 70	13			

1/ This does not include 13 natural nests that were considered in the total of 83 nests that were reported in the study.

Table 2.--*Summary comparison of reproductive performance*

Species and area	Number of nests	Eggs 1/						Young			
		Total		Hatched		Failed		Died		Assumed fledged	
		No.	Average	No.	Average	No.	Average	No.	Average	No.	Average
House wrens:											
Spray	9	60	6.7	53	5.9	7	0.8	0	0	53	5.9
Nonspray	5	27	5.4	22	4.4	5	1.0	6	1.2	16	3.2
Difference 2/			-1.3		-1.5		+.2		+1.2		-2.7
Mountain bluebirds:											
Spray	12	63	5.3	61	5.1	2	.2	0	0	61	5.1
Nonspray	47	246	5.2	229	4.9	17	.4	0	0	229	4.9
Difference 2/			-.1		-.2		+.2		0		-.2
Western bluebirds:											
Spray	1	6	6.0	5	5.0	1	1.0	0	0	5	5.0
Nonspray	9	44	4.9	44	4.9	0	0	0	0	44	4.8
Difference 2/			-1.1		-.1		-1.0		0		-.2

1/ Because of the timing of spray application, it was not possible for DDT to be involved in any differences in the numbers of eggs laid and eggs hatched.

2/ Nonspray minus spray.

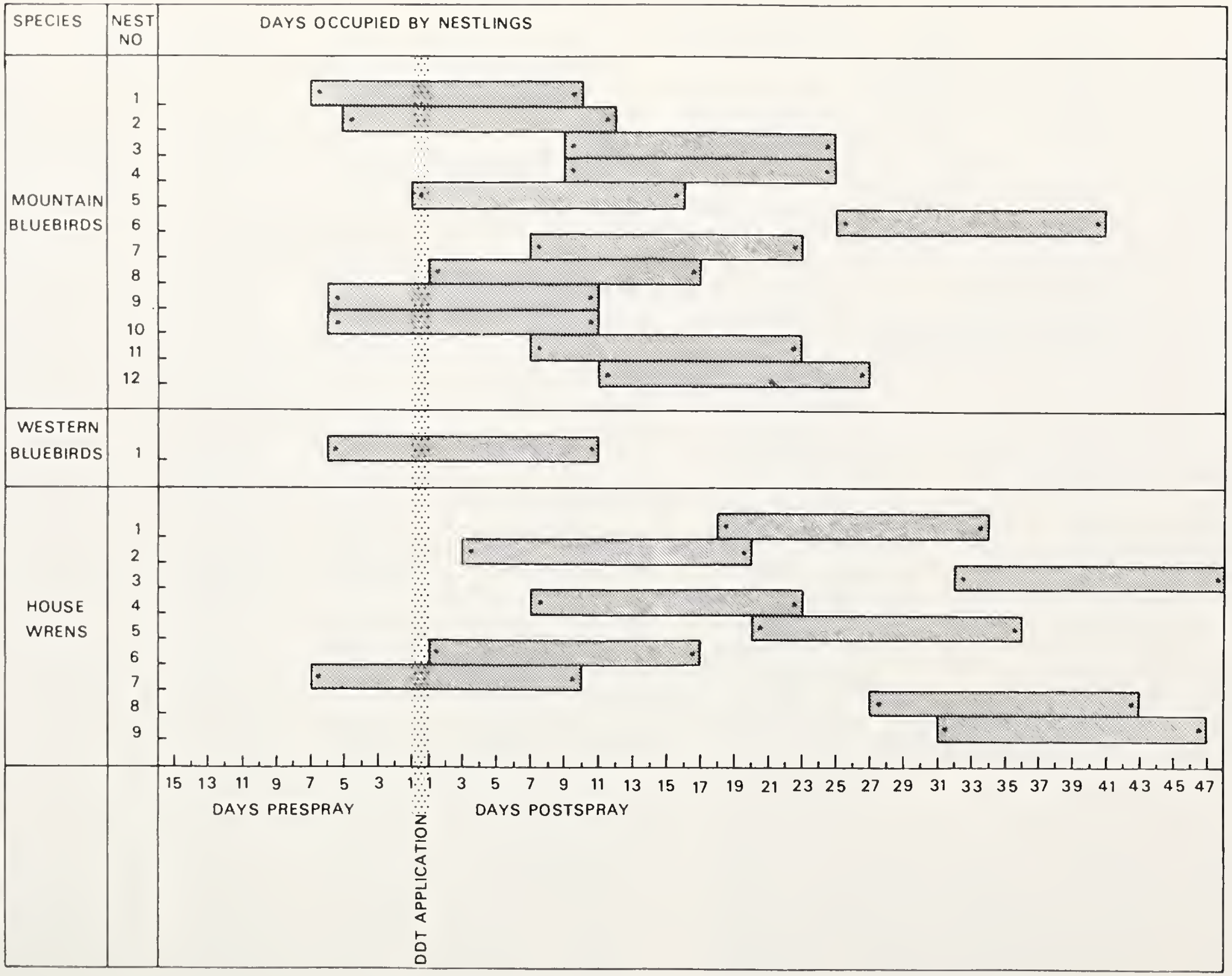

Figure 8.--Hatching and fledging dates and nest occupancy dates related to timing of DDT application. (Based on assumption of 16 days between hatching and fledging.)

NESTLING SURVIVAL

If DDT application affected reproductive performance, it could be demonstrated here only in terms of nestling survival. DDT was applied after the probable hatching dates for most of the nestlings observed in the spray areas (appendixes 7, 9, and 11, and fig. 8).

Power (1966) stated that mountain bluebirds demonstrated territorial behavior, flying up to one-quarter mile from their nests. Kendeigh (1941) reported that house wren territory varied with population level and averaged about 1 acre. He also stated that the wrens rarely left their territory during breeding season. Converting to the radius of a circle, we obtained 118 feet for travel from the territory center.

It was unlikely that many, if any, parents tending boxes in the spray areas traveled to nonspray areas to feed unless territories were expanded. We noted intense postspray feeding in areas of close proximity to the nest boxes. Distances from occupied boxes to nonspray areas ranged from 0.5 to 1.5 miles ($\bar{X}$ = 1.08) for mountain bluebirds, from 0.4 to 1.13 miles ($\bar{X}$ = 0.82) for house wrens, and was 0.75 mile for the Western bluebird.

There were no nestling losses detected for mountain bluebirds, in either spray or nonspray areas (table 2).

In the case of house wrens, no nestling deaths were recorded among 53 young in 9 nests, and the average fledged per nest was 5.9 (table 2). As performance in terms of nestling survival was perfect, it was obvious that DDT had no adverse influence in this regard. This precluded the necessity to test results against those from nonspray areas.

Fledging data were circumstantially derived, i.e., the absence of young birds, dead or alive, was taken to mean the birds fledged. However, more concrete information was known (days of nestling survival post-DDT exposure), which was derived from the chronological nesting events (appendixes 7, 9, and 11).

After DDT exposure, 56 mountain bluebird nestlings survived a total of 560 days (ranging from 3 to 21 days) (table 3) without mortality. With house wrens, 28 nestlings survived 238 days (ranging from 6 to 12 days) (table 4) without loss. Five Western bluebird nestlings survived 15 days of exposure (table 5) without mortality. These data are presented merely to give some indication of the confidence that could be placed on the circumstantially derived estimates of young fledged in spray areas. The fact that no young died during those periods when losses could be detected with certainty supports assumptions made concerning no losses before fledging. Comparison of similar data from nonspray areas was inappropriate. Performance in spray areas by this criterion was perfect, and such comparison was academic.

LATE VS. EARLY NESTING

All three bird species involved were reported to nest twice (Bent 1948, 1949). Mitchell et al. (1953) indicated significant adverse effects of DDT on reproduction of bluebirds and house wrens in second or late nesting.

Table 3.--*Known days of survival for mountain bluebird nestlings after DDT exposure*

Nest	Young observed	Days between observations	Total survival days[1]
	Number		
1	6	11	66
2	5	11	55
3	4	11	44
4	5	11	55
5[2]	3	21	63
	2	11	22
6	4	7	28
7	5	10	50
8	6	11	66
9	5	3	15
10	6	11	66
11	5	6	30
12[3]	--	--	--
Total	56	--	560

[1] Total survival days = young observed x days between observations.

[2] The 2 sets of data for 1 nest result from the first observation showing 3 young and 2 eggs, the second observation 11 days later revealing 5 young, and the next, after another 10 days showing 5 young. Therefore, 3 birds were known to survive 21 days (3 birds x 21 days = 63 survival days) and 2 for 11 days (2 birds x 11 days = 22 survival days).

[3] Because of the particular circumstances of chronology of development and observation, the young in this nest were not observed. Therefore, there are no known number of survival days.

Table 4.--*Known days of survival for house wren nestlings after DDT exposure*

Nest	Young observed	Days between observations	Total survival days[1/]
	Number		
1	6	10	60
2[2/]	--	--	--
3	5	6	30
4[3/]	3	10	30
	2	8	16
5	3	10	30
6[2/]	--	--	--
7	3	12	36
8[2/]	--	--	--
9	6	6	36
Total	28	--	238

[1/] Total survival days = young observed x days between observations.

[2/] Because of the particular circumstances of chronology of development and observation, the young in this nest were observed only once. Therefore, there were no known number of survival days.

[3/] The 2 sets of data for 1 nest results from the first observation revealing 3 young and 2 unhatched eggs and the second observation 2 days later showing 5 young. The last observation before fledging was made 8 days later and revealed 5 young. Therefore, 3 birds were known to have survived 10 days (3 birds x 10 days = 30 survival days) and 2 birds survived for 8 days (2 birds x 8 days = 16 survival days).

Table 5.--*Known days of survival for Western bluebird nestlings after DDT exposure*

Nest	Young observed	Days between observations	Total survival days[1/]
	Number		
1	5	3	15

[1/] Total survival days = young observed x days between observations.

We wanted to know if there were differences in the amount of late or second nesting between sprayed and nonsprayed areas. Power (1966) suggested, from studies in Montana, that nests started after July 1 were late nests. All nests were classified, by this criterion, as early or late nests using the chronology displays (appendixes 7-12).

These data are shown in tables 6 and 7. Testing was performed by means of chi-square in a test of independence with correction for continuity.

Results were: mountain bluebirds $\chi^2 = 0.09$ and species pooled $\chi^2 = 0.27$. Degrees of freedom were 1 in each case, and the null hypothesis ($p = 0.05$) was accepted in both cases. There were no differences in late nesting activity between spray and nonspray areas. Such tests for house wrens and Western bluebirds were inappropriate due to too few entries and zero cells.

DDT LEVELS IN THE SPRAY AREA

DDT spray reaching ground level around bluebird boxes averaged 0.220 gal per acre, ranging from 0.008 to 0.726[1/] for the three-card series at each box; averages were 0.090 inside the forest canopy, 0.180 at the forest edge, and 0.408 in the open (appendix 13).

For house-wren-occupied boxes, the average DDT spray level was 0.085 gal per acre, ranging from 0.008 to 0.280 with 0.057 inside the forest canopy, 0.076 at the edge, and 0.105 in the openings (appendix 14). The differences in the means for DDT levels were not significant between mountain bluebird and house wren nests ($p = 0.05$, $t = 1.4451$, d.f. = 18).

The DDT spray values for the one sprayed, Western bluebird nest were unknown inside the forest, 0.100 at the edge, and 0.300 in the opening (average 0.200).

The data for DDT spray reaching ground level at all boxes are in appendix 15.

Other cards were placed across openings of over 2 acres (openings of lesser size were sprayed) to judge if they received spray. The openings did receive widely variable amounts of spray (generally less than forested areas), and birds within sprayed areas had little access to DDT-free areas within our study boundaries. Yet, there were probably some grasslands within the spray area having very low DDT levels.

Data made available from 419 cards that were placed in these areas by other monitoring team members to judge overall spray patterns indicated an average of 0.24 gal DDT spray per acre reached ground level.

[1/] These data were not considered accurate beyond two decimal points. These figures resulted from interpolation between standard test cards.

Table 6.--*Distribution of nests started after July 1 by area and species*

Species and nest start	Area		
	Nonspray	Spray	Total
	- - - - - - - - - *Number* - - - - - - - - - -		
Mountain bluebird:			
Early	39	11	50
Late	8	1	9
Total	47	12	59
House wren:			
Early	4	6	10
Late	1	3	4
Total	5	9	14
Western bluebird:			
Early	7	1	8
Late	2	0	2
Total	9	1	10
All:			
Early	50	18	68
Late	11	4	15
Total	61	22	83

Table 7.--*Nests included in the late nest category*[1/]

Species	Area	
	Nonspray	Spray
Mountain bluebird	6, 9, 16, 20, 29, 31, 37, 47	6
House wren	1	3, 8, 9
Western bluebird	1, 5	

[1/] Nest identification numbers correspond to those found in all tables and appendixes containing nest data.

The amount of DDT that reached ground level was a fraction of the 0.75 lb per acre thought to have been applied (table 8). In the case of occupied mountain bluebird boxes, 22.0 percent (0.165 lb per acre) of the application rate reached ground level compared with 8.5 percent (0.063 lb per acre) for house wrens. The percentage for all occupied boxes was 16.6 percent.

Tarrant et al. (1972) reported that the aerial application of 0.75 lb per acre of DDT on vegetatively similar areas near Burns, Oregon, resulted in 26.0 percent (about 0.195 lb per acre) of the DDT reaching the soil surface under forest canopy. This was not markedly different from the levels recorded in this study.

Strickler and Edgerton (1970), working in the same area under various canopy cover situations (29, 52, and 57 percent), reported that 46.7, 49.3, and 45.3 percent, respectively, of the application rate of 0.75 lb DDT per acre reached ground level.

There was a marked increase in spray reaching the ground from inside the canopy toward the opening (table 8). Maksymiuk (1963b) indicated that locations such as those we used for our cards at the forest edge and 60 feet toward the opening were still subject to screening by tree cover, with 16 to 43 percent of the spray that reached the ground 180 feet from the nearest tree being screened out. He commented that, "It can be that there is little or no screening effect when cards are placed at distances greater than three tree heights away from the nearest tree. However, at shorter distances the deposit on the cards is not a true measure of that on the surrounding forest area."

Table 8.-- *Spray and DDT reaching ground level*[1] *at occupied boxes and clusters*

Location[2]	In forest		At box		In open		Total	
	Gal per acre	DDT per acre[3]	Gal per acre	DDT per acre[3]	Gal per acre	DDT per acre[3]	Gal per acre	DDT per acre[3]
Occupied boxes:								
Mountain bluebirds	0.090	0.067	0.180	0.135	0.408	0.306	0.220	0.165
House wrens	.057	.042	.076	.057	.105	.078	.085	.063
Combined	.069	.051	.129	.096	.281	.210	.166	.124
Clusters--all boxes:								
Powatka Ridge	.150	.112	.106	.079	.182	.136	.146	.109
McAllister Ridge	.074	.055	.086	.064	.278	.208	.134	.100
Horseshoe Ridge	.077	.057	.084	.063	.097	.072	.088	.066
McAllister	.061	.045	.114	.085	.325	.243	.174	.130
Combined	.089	.066	.097	.072	.208	.156	.131	.098

[1] See appendixes 13, 14, and 15 for details.

[2] Occupied boxes were included in the data for clusters, as DDT was applied after bird occupancy selections and was not influenced by spray application.

[3] DDT per acre = (gal per acre) (0.75 lb DDT per gal).

RESPONSE OF INSECT POPULATIONS TO DDT SPRAY

Data on insect matter obtained from malaise traps are shown in figure 7 and appendix 16. The trapping rate declined, in general, on both areas from samples taken in mid-June to the last ones taken before spray application on June 23 and 24.

However, when the last samples before spray were compared with first postspray samples, a marked difference in percentage population decline was evident between spray (80.7 percent) and nonspray areas (41.9 percent). Further, the mean milligram per trap per day of insect matter in the spray area was 48.0 percent of that in nonspray area immediately after spray application (37 vs. 77 percent).

These data are merely an index to general insect populations. There was a decline in this measure of the insect population probably due to DDT; this depression extended from June 23 and 24 to at least July 15, coinciding with that period when most nests contained nestlings being fed insects (fig. 7).

OBSERVATIONS

An immature robin (*Turdus migratorius*) and an unidentified nestling were found dead following spraying; none were found on the control areas.

Discussion

DDT could not have had an influence on the number or fertility of eggs, as DDT was applied after eggs were laid. If adverse effects were to be detected, it would have been in the form of nestling mortality.

Spray was applied, in most cases, after laying was complete (fig. 8). We detected no adverse effect of the aerial application of DDT on nestling survival of mountain bluebirds and house wrens.

Mitchell et al. (1953) showed fledging success of house wrens was 28 percent with such spray timing compared with 86 percent in unsprayed areas, while earlier prehatch spray had little effect. The application rate in this study was 25 percent of the 3 lb per acre in the Mitchell et al. (1953) study where nest boxes were located in open fields insuring that more DDT reached ground level. In spray application on forested areas, spray reaching the ground would be less. In view of these differences our results are perhaps, not surprising.

The success (percent of eggs hatched and percent young fledged) of the nests we observed seemed inordinately high. When it was considered that we detected no adverse effects of DDT, data for the areas were pooled. Results are shown in table 9. In total, 92.8 percent of the eggs hatched, and 91.4 percent of the eggs resulted in fledged birds.

Hole nesters have been reported to have a decided advantage over open nesters in the percentage of eggs that result in fledging (Beebe 1974). Our fledging levels are greater than the 65 percent success for hole nesters indicated by Nice (1937) and the 66 percent (based on a sample of 94,400 eggs) reported by Nice (1957).

Table 9.--*Success rates--percentages of eggs hatched and eggs resulting in fledged young*

Species	Number of:			Percent hatched	Number fledged	Percent fledged[1/]
	Nests	Eggs	Hatched			
House wren	14	87	75	86.2	69	79.3
Mountain bluebird	59	309	290	93.8	290	93.8
Western bluebird	10	50	49	98.0	49	98.0
All	83	446	414	92.8	408	91.4

1/ As a percentage of eggs laid.

One or a combination of two factors may be involved: (1) nest boxes are even more effective than natural cavities in enhancing reproductive success or (2) our assumptions concerning fledging may not be correct.

Because the hatching rate (92.8 percent), which was actually observed and therefore verified, was also decidedly higher than the average of 73 percent reported for hole nesters by Kalmbach (1939), we believe the high success to be related to nest box protection.

Our results on survival were tabulated on the basis of nestling survival. All nestlings examined appeared to be in good health. We have no data on differential survival after fledging.

If spray was shut off and then turned on when the helicopters crossed the forest edge bordering on grassland openings of greater than 2 acres, the variability in DDT reaching ground level in these edges would likely be greater than at any other location. It should be recognized, then, that this study did not deal, precisely, with the potential effects on nestling survival of bluebirds and house wrens of a constant application rate of 0.75 lb DDT per acre. Rather, it measured the effects of such application subject to the spray shut off and release near the forest-grassland edge. These data should not be extrapolated to other species of insectivorous birds nor to other habitat types within the spray area. Further, this study treated only the short-term DDT effects on nestling survival.

In summary, we detected no detrimental short-term effects on nestling survival of mountain bluebirds and house wrens on study areas sprayed with 0.75 lb DDT per acre subject to spray shut off and release over forest-grassland edges adjacent to grassland areas greater than 2 acres in size.

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Appendix Tables

Appendix 1.--*Reproductive data for mountain bluebirds in the spray area*

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-*Number*-	-*Percent*-	-*Number*-	-*Percent*-	-*Number*-	-*Percent*-	-*Number*-	-*Percent*-
1	6	6	100	0	0	0	0	6	100
2	6	5	83.3	1	16.7	0	0	5	100
3	4	4	100	0	0	0	0	4	100
4	5	5	100	0	0	0	0	5	100
5	5	5	100	0	0	0	0	5	100
6	5	5	100	0	0	0	0	5	100
7	5	5	100	0	0	0	0	5	100
8	6	6	100	0	0	0	0	6	100
9	5	5	100	0	0	0	0	5	100
10	6	6	100	0	0	0	0	6	100
11	5	5	100	0	0	0	0	5	100
12	5	4	80	1	20	0	0	4	100
Totals	63	61	96.8	2	3.2	0	0	61	100
$\overline{X}$	5.3	5.1		.2		0		5.1	

Appendix 2.--Reproductive data for mountain bluebirds in the nonspray area

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-Number-	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*
1	5	4	80	1	20	0	0	4	100
2	6	6	100	0	0	0	0	6	100
3	6	6	100	0	0	0	0	6	100
4	5	5	100	0	0	0	0	5	100
5	5	5	100	0	0	0	0	5	100
6	5	5	100	0	0	0	0	5	100
7	5	5	100	0	0	0	0	5	100
8	6	6	100	0	0	0	0	6	100
9	4	4	100	0	0	0	0	4	100
10	5	5	100	0	0	0	0	5	100
11	4	4	100	0	0	0	0	4	100
12	6	4	66	2	34	0	0	4	100
13	6	5	83	1	17	0	0	5	100
14	6	6	100	0	0	0	0	6	100
15	6	6	100	0	0	0	0	6	100
16	5	5	100	0	0	0	0	5	100
17	6	4	66	2	34	0	0	4	100
18	5	5	100	0	0	0	0	5	100
19	6	6	100	0	0	0	0	6	100
20	6	6	100	0	0	0	0	6	100
21	5	5	100	0	0	0	0	5	100
22	7	5	71	2	29	0	0	5	100
23	5	3	60	2	40	0	0	3	100
24	5	0	0	5	100	--	--	--	--
25	7	7	100	0	0	0	0	7	100
26	6	6	100	0	0	0	0	6	100
27	5	4	80	1	20	0	0	4	100
28	4	4	100	0	0	0	0	4	100
29	5	5	100	0	0	0	0	5	100
30	5	5	100	0	0	0	0	5	100
31	6	6	100	0	0	0	0	6	100
32	5	5	100	0	0	0	0	5	100
33	5	5	100	0	0	0	0	5	100
34	5	5	100	0	0	0	0	5	100
35	6	6	100	0	0	0	0	6	100
36	4	4	100	0	0	0	0	4	100
37	5	5	100	0	0	0	0	5	100
38	4	4	100	0	0	0	0	4	100
39	3	2	66	1	34	0	0	2	100
40	6	6	100	0	0	0	0	6	100
41	6	6	100	0	0	0	0	6	100
42	5	5	100	0	0	0	0	5	100
43	6	6	100	0	0	0	0	6	100
44	6	6	100	0	0	0	0	6	100
45	4	4	100	0	0	0	0	4	100
46	3	3	100	0	0	0	0	3	100
47	5	5	100	0	0	0	0	5	100
Totals	246	229	93.1	17	6.9	0	0	229	100
$\bar{X}$	5.2	4.9		.4		0		4.9	100

Appendix 3. *Reproductive data for house wrens in the spray area*

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-Number-	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*
1	6	6	100	0	0	0	0	6	100
2	7	7	100	0	0	0	0	7	100
3	5	5	100	0	0	0	0	5	100
4	7	5	71.4	2	28.6	0	0	5	100
5	7	6	85.7	1	14.3	0	0	6	100
6	8	8	100	0	0	0	0	8	100
7	8	7	87.5	1	12.5	0	0	7	100
8	6	3	50.0	3	50.0	0	0	3	100
9	6	6	100.0	0	0	0	0	6	100
Totals	60	53	88.3	7	11.7	0	0	53	100
$\bar{X}$	6.7	5.9		.77		0		5.9	

Appendix 4.--*Reproductive data for house wrens in the nonspray area*

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-Number-	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*
1	5	0	0	5	100	--	--	--	--
2	4	4	100	0	0	0	0	4	100
3	6	6	100	0	0	0	0	6	100
4	6	6	100	0	0	0	0	6	100
5	6	6	100	0	0	6	100	0	0
Totals	27	22	81.5	5	18.5	6	27.3	16	72.7
$\bar{X}$	5.4	4.4			1.0	1.5		4.0	

Appendix 5.--*Reproductive data for Western bluebirds in the spray area*

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-Number-	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*
1	6	5	83.3	1	16.7	0	0	5	100

Appendix 6.--*Reproductive data for Western bluebirds in the nonspray area*

Nest number	Eggs					Young			
	Number laid	Hatched		Failed		Died		Fledged	
		-Number-	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*	*-Number-*	*-Percent-*
1	5	5	100	0	0	0	0	5	100
2	5	5	100	0	0	0	0	5	100
3	5	5	100	0	0	0	0	5	100
4	3	3	100	0	0	0	0	3	100
5	4	4	100	0	0	0	0	4	100
6	6	6	100	0	0	0	0	6	100
7	5	5	100	0	0	0	0	5	100
8	6	6	100	0	0	0	0	6	100
9	5	5	100	0	0	0	0	5	100
Totals	44	44	100	0	0	0	0	44	100
$\bar{x}$	4.9	4.9		0		0		4.9	

Appendix 7.--Chronology of nesting activity — mountain bluebirds in spray areas

Status (JUNE – JULY)

Nest number	June 4	June 6	June 12	June 17	June 18	June 19	June 21	June 22	June 23	June 24	June 25	July 3	July 5
1	E (6)				E(2) Y(4)					*	Y (6)		Y (6)
2	E (6)				E (6)					*	Y (5)		Y (5)
3	√					E (3)				*	E (4)		Y (4)
4	√					E (5)				*	E (5)		Y (5)
5	√					E (5)				*	E(2) Y(3)		Y (5)
6	√					√				*	NB		E (5)
7			√				E (5)		*		E (5)	Y (5)	
8			E (6)				E (6)		*		Y (6)	Y (6)	Y (6)
9			E (5)				Y (5)		*		Y* (5)	YF (5)	
10			E (6)				Y (6)				*	Y (6)	Y (6)
11		√		E (5)				*			E (5)		Y (5)
12		√		E (5)				*			E (5)		

Status (JULY (Cont.) – AUGUST)

Nest number	July 10	July 12	July 15	July 21	July 22	July 24	July 30	August 7
1			YF (6)					
2			YF (5)					
3			Y (4)			YF (4)		
4			Y (5)			YF (5)		
5			Y (5)			YF (5)		
6			E (5)			Y(4) E(1)	Y(4) E(1)	YF (4)
7		Y (5)		YF (5)				
8								
9								
10		YF (6)						
11	Y (5)				YF (5)			
12	Y(4) E(1)				YF (4)			

LEGEND

√ = checked; no activity
E(1) = Eggs (number present)
Y(1) = Young (number present)
YF(1) = Young fledged (number fledged)
NB = Nest building
(shading) = Best estimate of time from hatching to fledging
* = Date of spray application

Appendix 8.--Chronology of nesting activity – mountain bluebirds in nonspray areas

Nest number	Status (Cont.) — JULY (Cont.)	Status (Cont.) — AUGUST
1	16: Y(4) E(1); 23: YF (5)	
2		
3		
4	16: YF (5)	
5		
6	23: E (5); 30: Y (5)	7: YF (5)
7		
8 and 9	23: Y (4); 30: YF (4)	
10		
11		
12	23: YF (4)	
13		
14		
15		
16	23: Y (5); 30: YF (5)	
17		
18		
19		
20	28: YF (6)	
21		
22	19: Y(5) E(2); 27: YF (5)	
23	19: YF (3)	
24	19: E (5)	
25	19: YF (7)	
26		
27	19: YF (4)	
28	19: YF (4)	
29	19: Y (5); 29: YF (5)	
30	17: YF (5)	
31	17: E (6); 30: Y(4) E(2)	15: YF (6)
32	17: YF (5)	
33	17: Y (5); 30: Y (5)	15: YF (5)
34	17: YF (5)	
35		
36		
37	28: YF (5)	
38		
39	22: YF (2)	
40	22: YF (6)	
41	22: YF (6)	
42		12: YF (5)
43		
44	22: YF (6)	
45	22: YF (4)	
46	23: YF (3)	
47	28: YF (5)	

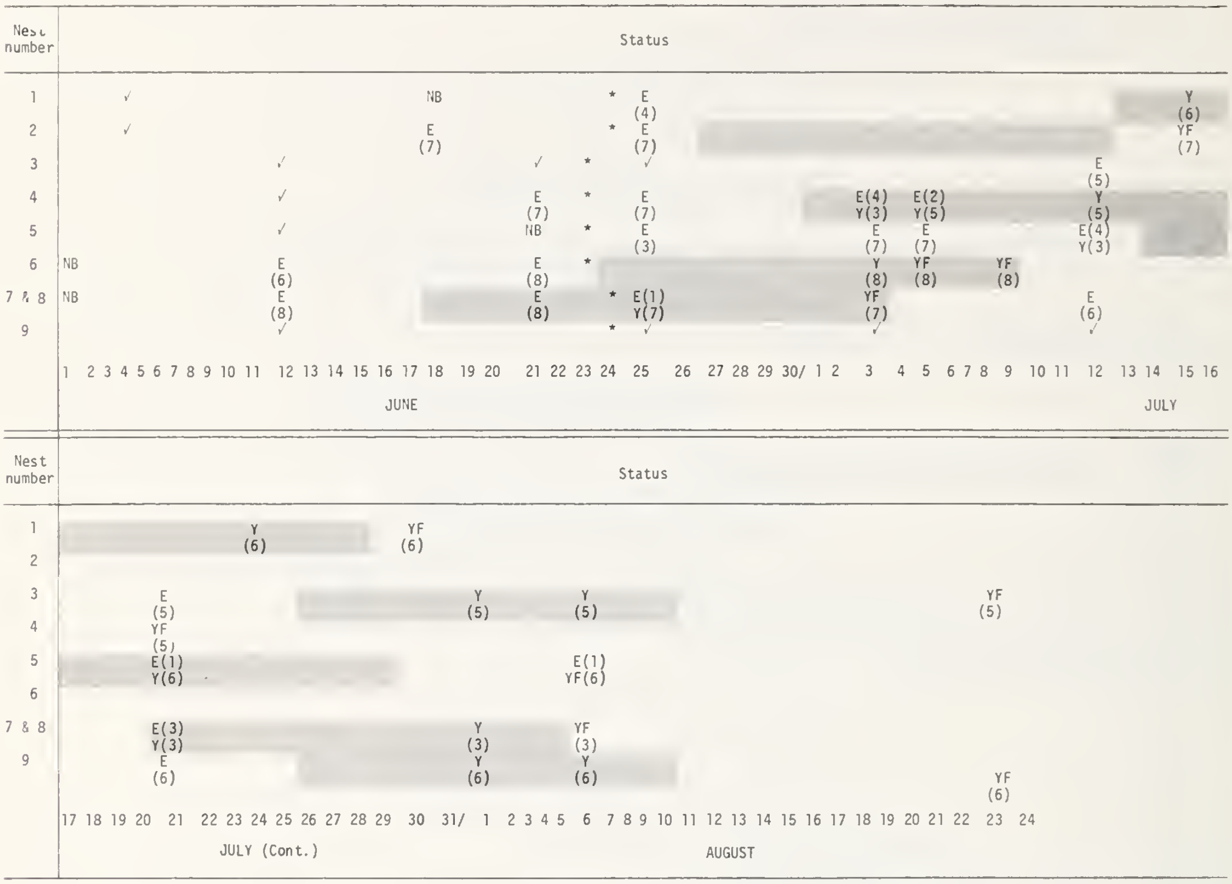
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31/1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

JULY (Cont.) AUGUST

LEGEND

- √ = checked; no activity
- E(1) = Eggs (number present)
- Y(1) = Young (number present)
- YF(1) = Young fledged (number fledged)
- NB = Nest building
- (grey bar) = Best estimate of time from hatching to fledging

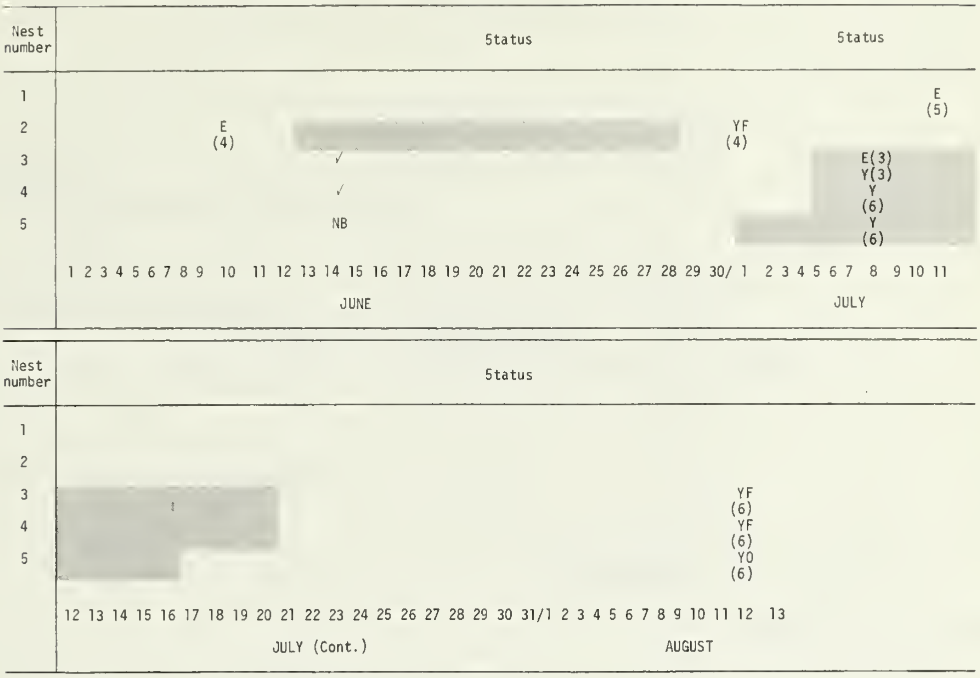
Appendix 9.--Chronology of nesting activity — house wrens in spray areas



LEGEND

✓ = checked; no activity
E(1) = Eggs (number present)
Y(1) = Young (number present)
YF(1) = Young fledged (number fledged)
NB = Nest building
(shaded bar) = Best estimate of time from hatching to fledging
* = Date of spray application

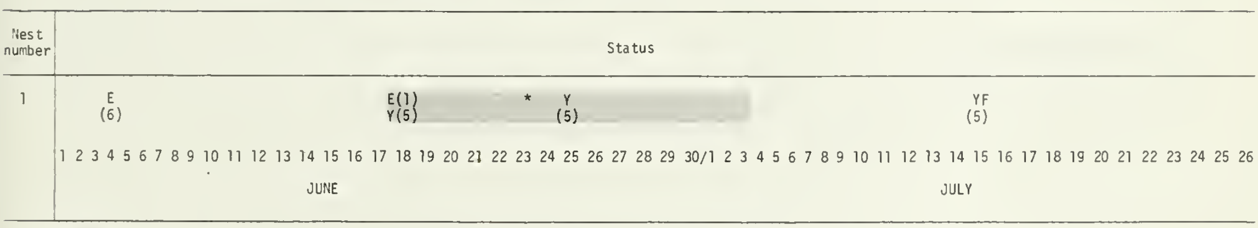
Appendix 10.--Chronology of nesting activity — house wrens in nonspray areas



LEGEND

√ = checked; no activity
E(1) = Eggs (number present)
Y(1) = Young (number present)
YF(1) = Young fledged (number fledged)
NB = Nest building
= Best estimate of time from hatching to fledging

Appendix 11.--Chronology of nesting activity — Western bluebirds in the spray area



LEGENO

E(1) = Eggs (number present)
Y(1) = Young (number present)
YF(1) = Young fledged (number fledged)
* = Date of spray aoplication
= Best estimate of time from hatching to fledging

Appendix 12.--Chronology of nesting activity — Western bluebirds in the nonspray area

LEGEND

√ = checked; no activity
E(1) = Eggs (number present)
Y(1) = Young (number present)
YF(1) = Young fledged (number fledged)
NB = Nest building
= Best estimate of time from hatching to fledging

Appendix 13.--*DDT spray (gal per acre)*[1] *reaching ground level at each occupied nest box in the spray area -- mountain bluebirds*

Nest number	In forest	At box	In open	Average
1[2]	0	--	0	0
2	.340	0.340	1.500	.726
3	.030	.075	.300	.135
4	.150	.150	.300	.200
5	.112	.450	.300	.287
6	.075	.060	.300	.145
7	--	.030	.075	.052
8	.008	.004	.015	.008
9	.008	.008	.008	.008
10	.075	.562	1.500	.712
11	.037	.075	.300	.137
12	.150	.225	.300	.225
Totals	.985	1.979	4.898	2.635
$\bar{X}$	.090	.180	.408	.220

1/ DDT per acre = (gal per acre) (0.75 lb DDT per gal).

2/ While this box, according to the spray cards, received no spray, it was included because it was surrounded by sprayed areas.

Appendix 14.--*DDT spray (gal per acre)*[1/] *reaching ground level at each occupied nest box in the spray area -- house wrens*

Nest number	In forest	At box	In open	Average
1	--	0.260	0.300	0.280
2	0.008	.008	--	.008
3	0	.008	.052	.020
4	.075	.008	.015	.033
5	.150	.015	.300	.155
6	.075	0	0	.025
7 & 8	.082	.015	.045	.047
9	.008	.300	.026	.111
Totals	.398	.614	.738	.679
$\bar{X}$	.057	.076	.105	.085

1/ DDT per acre = (gal per acre) (0.75 lb DDT per gal).

Appendix 15.--*DDT spray (gal per acre)*[1/] *reaching ground level in each study location*

Cluster	In forest			At box			In open		
	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.
Powatka Ridge	40	0.150	0.108	41	0.106	0.032	41	0.182	0.043
McAllister Ridge	33	.074	.063	37	.086	.075	26	.278	.217
Horseshoe Ridge	58	.077	.011	58	.084	.014	57	.097	.017
McAllister	41	.061	.057	44	.114	.098	48	.325	.219

1/ DDT per acre = (gal per acre) (0.75 lb DDT per acre).

Appendix 16.--Rate of capture (mg per day) of insects in malaise traps--spray areas vs. nonspray areas[1/]

Day number[2/]		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Area	Trap number	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3
										June									*July*	
Spray	1	472	--	--	375	--	--	--	--	253	--	--	--	--	37	--	--	--	--	--
	2	119	--	--	76	--	--	--	--	54	--	--	--	--	9	--	--	--	--	--
	3	569	--	--	461	--	--	--	--	314	--	--	--	--	52	--	--	--	--	13
	4	608	--	--	232	--	--	--	--	--	--	--	--	--	28	--	--	--	--	35
	5	--	--	405	--	--	--	--	--	--	--	--	123	--	--	--	--	--	--	--
	6	--	--	151	--	--	--	--	87	--	--	--	--	--	5	--	--	--	--	--
	7	--	35	--	--	--	--	--	13	--	--	--	--	--	8	--	--	--	--	--
Nonspray	1	120	--	--	65	--	--	--	--	75	--	--	--	--	51	--	--	--	--	--
	2	--	--	302	--	--	--	--	--	--	--	--	--	153	--	--	--	--	--	--
	3	186	--	--	231	--	--	--	--	207	--	--	--	--	82	--	--	--	--	--
	4	195	--	--	262	--	--	--	--	40	--	--	--	--	48	--	--	--	--	--
	5	--	29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	6	--	137	--	--	--	--	--	--	50	--	--	--	--	--	--	--	--	--	--

Day number[2/]		34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Area	Trap number	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
										July (Cont.)												
Spray	1	--	--	--	--	--	37	--	--	--	--	--	--	--	--	--	--	--	--	--	159	--
	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	23	--	--	--	--	--	--	--	--	--	--	--	--
	4	--	--	--	--	--	--	--	--	19	--	--	--	--	--	--	--	--	--	--	--	--
	5	--	15	--	--	--	--	--	--	--	--	--	16	--	--	--	--	--	--	--	--	39
	6	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	7	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonspray	1	--	--	--	--	--	41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2	--	87	--	--	--	--	--	--	--	--	--	66	--	--	--	--	--	--	--	--	178
	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	170	--
	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	36	--
	5	--	--	--	--	75	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	6	--	--	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[1/] Data presented here correspond to the data points in figure 1.

[2/] Day numbers correspond to standard day numbers for all appendixes.

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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